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MINIMAL MAINTENANCE LINK TO SUPPORT SYNCHRONIZATION

RELATED APPLICATION

This application claims the benefit of U.S.
Provisional Application Serial No. 60/180,598 filed on
5   February 7, 2000, the entire teachings of which is
incorporated herein by this reference.

BACKGROUND OF THE INVENTION

Increasing use of wireless telephones and personal
computers has led to a corresponding increase in demand for
10   advanced telecommunication services that were once thought
practical only for specialized applications. In the 1980s,
wireless voice communication became widely available
through cellular telephone networks. Such services were
thought at first to be the exclusive province of the
15   businessman because of expected high subscriber costs. The
same was also true for access to remotely distributed
computer networks, whereby until very recently, only
business people and large institutions could afford the
necessary computers and wireline access equipment.
20   As a result of the widespread availability of
affordable new technologies, the general population now
increasingly desires to have not only wireline access to

networks such as the Internet and private intranets, but also wireless access as well. Wireless technology is particularly useful to users of portable computers, laptop computers, hand-held personal digital assistants and the

5 like who prefer access to such networks without being tethered to a telephone line.

There still is no widely available satisfactory solution for providing low cost, high speed access to the Internet, private intranets, and other networks using the

10 existing wireless infrastructure. This is most likely an artifact of several unfortunate circumstances. For one, the typical manner of providing high speed data service in the business environment over a wireline network is not readily adaptable to the voice grade service available in

15 most homes or offices. Such standard high speed data services also do not lend themselves well to efficient transmission over standard cellular wireless handsets because wireless networks were originally designed only to provide voice services. As a result, present day digital

20 wireless communication systems are optimized for voice transmissions, although certain schemes such as CDMA do provide some measure of asymmetrical behavior for the accommodation of data transmission. For example, the data rate specified by the Telecommunication Industry

25 Association (TIA) for IS-95 on the forward traffic channel is adjustable in increments from 1.2 kbps up to 9.6 kbps for so-called Rate Set 1, and increments from 1.8 kbps up to 14.4 kbps for Rate Set 2. On the reverse link traffic channel, however, the data rate is fixed at 4.8 kbps.

30 Existing wireless systems therefore typically provide a radio channel that can accommodate maximum data rates only in the range of 14.4 kilobits per second (kbps) at

best in the forward direction. Such a low data rate
channel does not lend itself directly to transmitting data
at rates of 28.8 or even 56.6 kbps that are now commonly
available using inexpensive wireline modems, not to mention

5   even higher rates such as the 128 kbps that are available
with Integrated Services Digital Network (ISDN) type
equipment. Data rates at these levels are rapidly becoming
the minimum acceptable rates for activities such as
browsing web pages.

10   Although wireline networks were known at the time when
cellular systems were initially developed, for the most
part, there was no provision made for such wireless systems
to provide higher speed ISDN- or xDSL-grade data services
over cellular network topologies.

15   In most wireless systems, there are many more
potential users than radio channel resources. Some type of
demand based multiple access is therefore required.

        Whether the multiple access is provided by the
traditional Frequency Division Multiple Access (FDMA) using

20 analog modulation on a group of radio frequency carrier
signals, or by schemes that permit sharing of a radio
carrier frequency using Time Division Multiple Access
(TDMA), or Code Division Multiple Access (CDMA), the nature
of the radio spectrum is such that it is a medium that is

25 expected to be shared. This is quite dissimilar to the
traditional environment for data transmission, in which the
wireline medium is relatively inexpensive to obtain and is
not typically intended to be shared.

        Other factors to consider in the design of a wireless

30 system are the characteristics of the data itself. For
example, consider that access to web pages in general is
burst-oriented, with asymmetrical data rate transmission

requirements in a reverse and forward direction. Typically, the user of a remote client computer first specifies the address of a web page to a browser program. The browser program then sends this web page address data,

5   which is usually 100 bytes or less in length, over the network to a server computer. The server computer then responds with the content of the requested web page, which may include anywhere from 10 kilobytes to several megabytes of text, image, audio, or even video data. The user

10   thereafter may spend several seconds or even several minutes reading the content of the page before downloading another web page.

In an office environment, the nature of most employees' computer work habits is typically to check a few

15   web pages and then to do something else for an extended period of time, such as accessing locally stored data or even terminating use of the computer altogether. Therefore, even though such users may remain connected to the Internet or private intranet continuously during an

20   entire day, actual use of the high speed data link usually quite sporadic.

If wireless data transfer services supporting Internet connectivity are to coexist with wireless voice communication, it is becoming increasingly important to

25   optimize the use of available resources in wireless CDMA systems. Frequency re-use and dynamic traffic channel allocation address some aspects of increasing the efficiency of high performance wireless CDMA communication systems, but there is still a need for more efficient

30   utilization of available resources.

SUMMARY OF THE INVENTION

The present invention provides several novel features
for optimizing wireless links in a CDMA communication
system. In general, a coded channel is dedicated for
5   carrying adjustment messages to maintain synchronization of
links between a base station and each of multiple field
units. Accordingly, the system is capable of supporting
higher throughput data transfers due to reduced co-channel
interference.

10   In an illustrative embodiment, a first forward link
channel is allocated to support message transmissions from
a base station to each of multiple field units. A second
reverse link channel is allocated to support message
transmissions from the field units back to the base
15   station. Each channel is partitioned into time slots,
where a time slot in the first channel is assigned to a
field unit for directing communications from the base
station to the corresponding field unit. Likewise, a time
slot in the second channel is assigned for use by a field
20   unit to transmit messages to the base station. Based on
the assignment, the time slot itself indicates to which
field unit a message is directed. Timing alignment of the
first and second channels is achieved by adjusting
respective timing of one channel based upon message
25   transmissions indicating how to achieve synchronization.

Preferably, the first channel is partitioned to
include both "active" and "standby" time slots, where an
active time slot corresponds to a field unit transmitting a
data payload such as digital web page information to the
30   base station on the reverse link.

The base station monitors the field units,
acknowledging requests by corresponding field units to be

placed in the active mode. If available, an active time
slot is assigned to the link requesting field unit and
traffic channels are allocated in the reverse link to
support a data payload transfer between the requesting
5 field unit and the base station. Following a data transfer
on a particular link, the field unit is reassigned to a
standby time slot for maintaining a minimal but
synchronized link with the base station.

In a preferred embodiment, there are a predetermined
10 number of periodically repeating time slots allocated
within each of the first and second channels. Hence,
messages from the base station or field units are
transmitted on a periodic basis in the appropriate time
slots. Preferably, a time slot assigned to a field unit in
15 the first channel for receiving data from the base station
is offset in time with respect to the time slot assigned in
the second channel for transmitting data from the field
unit to the base station.

Messages received at the base station in assigned time
20 slots from each of many field units are analyzed to
determine how to adjust the timing of future message
transmissions at the corresponding field units. In
particular, timing alignment of a field unit is adjusted so
that a message is received at the base station in the
25 assigned time slot. This is achieved by transmitting a
timing adjustment message from the base station over the
forward link to the field unit indicating whether the field
unit should advance or retard timing of future message
transmissions. In this way, field units transmitting
30 messages in adjacent time slots of the same reverse link
channel typically will not interfere with each other.

Messages transmitted over a reverse link channel from a field unit to the base station preferably include markers that are monitored at the base station for synchronizing the corresponding field unit with the base station. The

5   marker transmitted in a message provides a reference point within a time slot for generating timing correction information as described above. Preferably, a well-placed string of pilot symbols is used as a time reference marker in a time slot. Alternatively, a short pseudorandom noise

10   (PN) code may be used as a marker in a time slot.

While in the active mode, a marker in a corresponding time slot of the traffic channels is analyzed to support timing alignment between the field unit and base station. While in the inactive or standby mode, a marker in a time

15   slot of the second channel is analyzed to support timing alignment between the field unit and base station.

In a more specific application, the message sent from the base station to a field unit is a single bit indicating whether to advance or retard timing reference at the field

20   unit. Based on the state of the bit received at a corresponding field unit, the field unit then advances or retards its timing a predefined amount of time such as 1/8 of a chip. If a state of the single bit is in a same state n times in a row, i.e., n logic ones or zeros are received

25   in a row, a subsequent bit in the same state will cause the field unit to advance or retard its timing based on a larger predefined time such as ½ of a chip rather than 1/8 of a chip.

The base station monitors an access channel for

30   requests by field units to establish new links with the base station. The time a link request message is received at the base station is used to determine an initial timing

adjustment to be made by the requesting field unit for achieving timing synchronization with the base station.

More particularly, to achieve initial synchronization of time slots between the base station and field unit, a

5 coarse timing adjustment message is transmitted to a respective field unit indicating how to achieve timing alignment with the base station. The coarse timing adjustment message is preferably a multi-bit value notifying the field unit of an amount to advance or retard

10 its initial timing to achieve synchronization with the base station. Accordingly, this provides the field unit with a slot timing reference for receiving and transmitting messages in assigned time slots.

Preferably, the coarse timing adjustment message is

15 sent to the link requesting field unit over a paging channel. Likewise, time slot assignment information is transmitted to a field unit over the paging channel.

A set of short PN codes are optionally assigned to a field unit, where each code corresponds to a predefined

20 command or request. One of the codes is transmitted in an assigned time slot on the second channel from a field unit to communicate a message to the base station. In one instance, an assigned short PN code indicates a request by the field unit to transmit a data payload from the field

25 unit to the base station. Another short PN code is used to notify the base station that a field unit desires to remain in the standby mode. In a preferred embodiment, the short PN code is also used as a marker within a time slot to synchronize the first and second channel as mentioned

30 above.

One other aspect of the present invention is to provide a link between a base station and each of multiple

field units using minimal resources. Providing shared
channels using the methods as described above for
communicating with a base station reduces the number of
CDMA channels necessary to maintain synchronized links with
5   multiple field units. Accordingly, more channels are then
available to support data transfers between the base
station and field units. This increases the potential
throughput on an allocated carrier frequency since more
CDMA channels are available to support data payload
10   transfers.

Another aspect of the present invention is the recited
method for supporting timing alignment between the base
station and each of multiple field units. The base station
analyzes a time marker incorporated in each message
15   received in an assigned time slot to detect whether a field
unit message directed to the base station is early or late
with respect to a preferred time of receipt at the base
station. Accordingly, a message such as a single
advance/retard control bit is transmitted back to the
20   corresponding field unit to advance or retard its timing so
that future message transmissions from the field unit are
received at the base station in the appropriate time slot.
Thus, multiple field units transmitting messages on the
shared reverse link channel generally do not collide with
25   each other. Additionally, the timing information sent on
the forward link enables the field unit to synchronize
itself to the base station for receiving messages in its
assigned time slot on the forward link.

BRIEF DESCRIPTION OF THE DRAWINGS
30   The foregoing and other objects, features and
advantages of the invention will be apparent from the

following more particular description of preferred
embodiments of the invention, as illustrated in the
accompanying drawings in which like reference characters
refer to the same parts throughout the different views.

5 The drawings are not necessarily to scale, emphasis instead
being placed upon illustrating the principles of the
invention.

Fig. 1 is a general diagram illustrating a wireless
communication system according to the principles of the
10 present invention.

Fig. 2 is a timing diagram illustrating heartbeat slot
and link quality management (LQM) slot timing according to
the principles of the present invention.

Fig. 3 is a diagram illustrating the bit definition of
15 an LQM slot according to the principles of the present
invention.

Fig. 4 is a block diagram of components supporting
channel synchronization according to the principles of the
present invention.

20 Figs. 5a and 5b are a flow chart describing the
process of synchronizing forward and reverse channels
according to the principles of the present invention.

Fig. 6 is a graph illustrating pulse sampling of a
timing mark for synchronizing forward and reverse channels
25 according to the principles of the present invention.

Fig. 7 is a table showing attributes of the active,
standby and idle mode according to the principles of the
present invention.

30 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a diagram of a wireless communication system
100 according to the principles of the present invention.

A base station 25 maintains wireless communication links
with a plurality of field units 42A, 42B, 42C
(collectively, field units 42) as shown. Such wireless
links are established based upon assignment of resources on
5   a forward link 70 and a reverse link 65 between the base
station 25 and field units 42. Each link 65 or 70 is
typically made up of several logical channels 55 or 60.

System 100 supports wireless communications between
interface 50 and network 20. Network 20 is typically a
10 Public Switched Telephone Network (PSTN) or computer
network such as the Internet. Interface 50 is preferably
coupled to a digital processing device such as a portable
computer (not shown), to provide wireless access to network
20.

15   In an illustrative embodiment, the forward link
channels 60 and reverse link channels 55 are defined in the
wireless communication system 100 as Code Division Multiple
Access (CDMA) channels. That is, each CDMA channel is
preferably defined by encoding data to be transmitted over
20 the channel with an augmented pseudorandom noise (PN) code
sequence. The PN coded data is then modulated onto a radio
frequency carrier. This enables a receiver to decipher one
CDMA channel from another knowing only the particular
augmented PN code assigned to that channel. In accordance
25 with the preferred embodiment, each channel preferably
occupies a 1.25 MHz band consistent with the IS-95 CDMA
standard and is capable of transmitting data at 38.4 kbps.

The forward link channels 60 include at least three
logical channels. Included among these are a Link Quality
30 Management (LQM) channel 60L, a paging channel 60P, and
multiple traffic channels 60T.

The reverse link 65 includes a heartbeat channel 55H, an access channel 55A and multiple traffic channels 55T. Generally, the reverse link channels 55 are similar to the forward link channels 60 except that each reverse link
5 traffic channel 60T may support variable data rates from 2.4 kbps to a maximum of 160 kbps.

Data transmitted between base station 25 and a field unit 42 typically consists of encoded digital information, such as Web page data. Based on the allocation of traffic
10 channels in the reverse link 65 or forward link 70, data transfer rates are generally limited by the number of available traffic channels 55T.

As shown in Fig. 2, the forward link LQM channel 60L is partitioned into a predetermined number of periodically
15 repeating time slots for the transmission of messages to each of multiple field units 42. Each field unit 42A identifies messages directed to itself based upon messages received in an assigned time slot.

The reverse link heartbeat channel 55H is shared among
20 multiple users. For example, the heartbeat channel 55H is also partitioned into periodically repeating time slots. Each time slot is assigned to one of many field units 42 for transmitting heartbeat messages to the base station 25. Accordingly, the base station 25 identifies from which
25 field unit 42A a message is transmitted based upon the receipt of a message in a particular time slot. The heartbeat channel 55H and the LQM channel 60L are described in more detail below.

In the following description, reference is again
30 generally made to Fig. 1, but more specific details of LQM channel 60 and heartbeat channel 55H are referenced to Fig. 2.

To establish a synchronized link with the base station 25, field units 42 transmit link request messages on the access channel 55A to base station receiver 35 via field unit transmitter 40. Messages are then acknowledged and

5 processed at the base station 25. If available, resources are then allocated at the base station 25 to establish a bi-directional communication link with the requesting field unit 42A.

Within the forward link 70, the paging channel 60P is

10 used by the base station transmitter 30 to send overhead and paging messages or commands to the field unit receiver 45. Overhead information includes data such as system configuration parameters for establishing wireless links with field units 42.

15 As mentioned previously, wireless communication system 100 includes a heartbeat channel 55H in the reverse link 65 and link quality management channel (LQM) 60L in the forward link 70. These channels are shared between the base station 25 and multiple field units 42. That is, the

20 base station 25 transmits messages to multiple field units 42 using the same forward link LQM channel 60L, where a message to a particular field unit 42A is transmitted in an assigned time slot. In this way, time slot assignments serve as a way of addressing messages to a particular field

25 unit and corresponding communication link.

The principles of the present invention are advantageously deployed to support users that require on-demand, sporadic high speed throughput of data on a wireless communication link. For example, remote users

30 connected to the Internet over a wireless link typically require high speed throughput when downloading an object file such as a Web page. Such users then typically do not

require any data transfer for a period of time. To support
such users, it is advantageous to maintain synchronization
with the base station for future on-demand data transfers.
This is achieved in the wireless communication system 100

5 by maintaining a minimal connection with the base station
25 even when no data is being actively transferred between
the base station 25 and a specific field unit 42.

Repeatedly creating or reviving connections for users
who sporadically need a link can be time consuming and an

10 inefficient use of resources. It is also inefficient to
reserve resources such as traffic channels 55T for
subscribers who are not transmitting data. Accordingly,
traffic channels 55T are allocated on an as-needed basis to
support data transfers, optimizing the use of available

15 resources in wireless communication system 100.

Fig. 2 is a timing diagram for the heartbeat channel
55H and LQM channel 60L. Preferably, there are two LQM
channels 60L and two heartbeat channels 55H since channels
are typically allocated in pairs. However, only one of

20 each channel type is shown in Fig. 2 for illustrative
purposes.

As shown, 64 time slots (in each direction) are
defined per EPOCH period in each of the heartbeat 55H and
LQM 60L channels. The EPOCH period in the illustrated

25 embodiment is 13.3mS, so that each time slot is 208mS or
256 PN code chips. Because time slots repeat on a periodic
basis, base station 25 exchanges information with a
particular field unit 42A every EPOCH or 13.3mS.

Data transmissions on the LQM channel 60L are

30 maintained by the base station 25, which is preferably used
as a master timing reference. That is, timing of the field
units 42 is aligned with base station 25. Field units 42,

therefore, must synchronize themselves to the base station
25, and specifically to the LQM channel 60L, in order to
maintain synchronization with the base station 25.

Generally, a link between the base station 25 and a
5   field unit 42A is maintained in one of three modes: active,
standby or idle. Synchronization between base station 25
and a particular field unit 42A is maintained only for the
active and standby mode. Fig. 7 provides more details
about mode types maintained for a particular link between
10   the base station 25 and a field unit 42A.

Each field unit 42A in the standby mode is assigned
one time slot in the forward link LQM channel 60L and one
time slot in the reverse link heartbeat channels 55H.
Accordingly, information is targeted to a receiving field
15   unit 42A (subscriber) based upon the transmission of a
message in a particular time slot. For example, a field
unit 42A assigned to time slot #1 decodes information
received in time slot #1 on the forward link LQM channel
60L, while data is transmitted back to the base station 25
20   from field unit 42A in time slot #1 of the reverse link
heartbeat channel 55H. Both base station 25 and field unit
42A identify to which link a message pertains based on
receipt of a message in a particular time slot.

Preferably, there is a timing offset between time
25   slots in each respective channel allowing base station 25
time to process a message received in an assigned time slot
and then respond accordingly over the LQM channel 60L in a
following cycle. It should be noted that although the LQM
channel 60L is used as the time reference as described
30   above, the principles of the present invention equally
apply where the heartbeat channel 55H is alternatively used
as a master timing reference rather than the LQM channel

60L. In other words, base station 25 is optionally synchronized with respect to a field unit 42A.

In the standby mode, synchronization is maintained between the forward link LQM channel 60L and reverse link
5   heartbeat channel 55H based upon messages sent in the appropriate time slot on the LQM channel 60L indicating to a particular field unit 42A whether messages transmitted to the base station 25 from that field unit are received in the appropriate time slot. Message transmissions from the
10 field unit transmitter 40 to base station 25 on the heartbeat channel 55H are analyzed at base station receiver 35 to achieve fine tuning alignment between base station 25 and each of multiple field units 42.

As shown in Fig. 2, time slots A_1 through A_{16} of the
15 LQM channel 60L are reserved for field units 42 in the active mode, indicating that data is being transferred between the field unit 42A and the base station 25. Contrariwise, time slots numbered 1-48 are reserved for field units 42 operating in the standby mode on the LQM
20 channels 60L.

At any given time, there are typically no more than 48 time slots in the heartbeat channel 55H or LQM channel 60L assigned to respective field units 42. This ensures that on completion of a data transfer between a field unit 42A
25 and base station 25, a field unit 42A in the active mode assigned an active time slot can revert back to the standby mode and consequently be assigned an unused standby mode time slot 1-48 in the LQM channel 60L again.

Preferably, field units 42 in the standby mode are
30 assigned an unused active time slot as close to the EPOCH mark M1 as possible when they are placed in the active mode. For example, if 48 field units are assigned standby

mode LQM slots 1-48, a field unit 42A set to the active
mode would be assigned active mode time slot A1 in the LQM
channel. The next active time slot to be assigned to a
field unit 42A would be the lowest numbered and unused time

5   slot such as A2, assuming A1 is then in use.

Fig. 3 is a timing diagram illustrating the mapping of
bits in a forward link LQM time slot 310. As shown, there
are 16 bits transmitted in each time slot 310. The
adjustment message transmitted in time slot indicates

10   whether the corresponding field unit message transmission
received at the base station 25 on a last message cycle is
accurately received within the assigned time slot at base
station 25. This feedback loop ensures that other field
units 42 transmitting messages in adjacent time slots of

15   the same reverse link heartbeat channel 55H do not
interfere with each other.

In a preferred embodiment, the LQM timing bit 311
indicates whether a field unit 42A is to advance or retard
its timing on the reverse link 65. A logic one indicates

20   that timing should be advanced 1/8 of a chip while a logic
zero indicates that timing should be retarded 1/8 of a
chip. In this way, the base station 25 individually
synchronizes time slots and, therefore, communication links
between the base station 25 and each of a plurality of

25   field units 42. Said differently, timing of message
transmissions from corresponding field units 42 are
adjusted so that corresponding messages are received in the
assigned time slots at the base station 25.

In a preferred embodiment, the base station 25

30   transmits information on the LQM channel 60L based on BCH
coding. This enables a receiving unit to detect and
correct errors. For example, the use of a 15,7 code allows

up to 2 errors to be corrected and up to 3 errors to be
detected. As shown in Fig. 3, there are 8 parity bits 313
for error correction and detection.

Fig. 4 more particularly shows hardware at base
5   station 25 that is used to achieve synchronization of the
reverse link 65 and forward link 70. As discussed,
synchronization is achieved between a field unit 42A and
base station 25 based on the forward link LQM channel 60L
and reverse link heartbeat channel 55H.

10 It should be noted that each field unit 42A is
assigned a set of short PN codes, one of which is generally
to be transmitted in the assigned time slot in the reverse
link heartbeat channel 55H. Each code corresponds to a
particular command or request and is transmitted by a field
15 unit 42A to the base station 25. For example, one code is
used to notify the base station that the field unit 42A
needs to transmit a data payload to the base station, i.e.,
a field unit requests to go active.

Time slots assigned to each field unit 42A on the
20 heartbeat channel 55H are analyzed by heartbeat correlation
filters 440, 445. Basically, the short PN codes received
in a particular time slot are monitored to detect a request
by the corresponding field unit 42A to be placed in the
active mode. Thereafter, the base station 25 will set the
25 field unit 42A to the active mode by assigning it the
appropriate resources to transmit a data payload in the
reverse link direction to base station 25. Note that a
first heartbeat correlation filter 440 detects a short PN
code corresponding with a request to remain in the standby
30 mode, while a second heartbeat correlation filter 445 at
the base station 25 detects a short PN code corresponding
with a request to be placed in the active mode.

Regardless of the short PN code received in a time
slot, the information from the field unit 42A is monitored
by pulse timing analyzer 424. It is then determined
whether the message transmission by a corresponding field

5 unit 42A is received early or late within a time slot at
base station 25 by analyzing the corresponding signal.
Preferably, the strongest received diversity string will be
designated as the time alignment string at base station 25
for analyzing timing of the message received on the

10 heartbeat channel 55H.

Precise timing alignment is achieved using the
correlation profile of the pilot in a particular string,
which is analyzed as mentioned using correlation filters.
The output of the correlation filters 440, 445 consist of

15 256 samples, which represent 64 lags at 4 samples per lag.
The 256 sample output-window represents the total
correlation time span of base station 25. Preferably, the
time alignment point is sample number 80 which allows 20
lags for precursor and 44 lags for post cursor channel

20 information.

Generally, the computation of the time alignment error
is based on a determination of where the centroid or peak
lies in a given sample string. For example, each field
unit transmitting in its assigned time slot includes a

25 marker, i.e., the peak signal, located at a predetermined
position within a time slot. The strongest pilot path for
the channel and 2 samples on either side of the main path,
i.e., 1 and 1/4 chips, is statistically analyzed to
determine the centroid or peak of a marker within a time

30 slot. Location of the centroid, L, of the samples in Fig.
6 is calculated based on the following equation:

$$L = \frac{\sum [t \times Q(t)]}{\sum Q(t)}$$

where t= sample time and Q(t) is the magnitude of a sample at a given time.

For example, L is calculated based on the results as
5   shown in Fig. 6:

$$L = \frac{(.25*76)+(.5*77)+(1.0*78)+(.8*79)+(.6*80)}{.25+.5+1.0+.8+.6}$$

$$L = 78.317$$

Again, the timing alignment error is determined by comparing the timing of the computed centroid to the
10 desired time set point of 80, which is chosen as the reference point for timing alignment within a time slot. Since the centroid in the example above is estimated to be 78.317, timing is early and, therefore, the corresponding LQM timing bit 311 will be set to a logic "one" indicating
15 that the corresponding field unit should advance its timing by 1/8 of a chip. This overall feedback technique in the present invention ensures continuous fine tuning of time ahead alignment between the forward link LQM channel 60L and each of multiple field units 42 transmitting on the
20 reverse link heartbeat channel 55H.

Preferably, the time error is calculated by taking the integer of twice the difference between the desired set point sample 80 and L. For example,

time_error = integer [(L-80)*2]

If the time_error result is negative, the LQM timing
bit 311 is set to a logic "one." Conversely, it is set to
a logic "zero" when time_error is positive.

5   Processor 426 analyzes timing data and generates
time_error for synchronizing the reverse link heartbeat
channel 55H and forward link LQM channel 60L. LQM time
slotted messages are then transmitted by LQM signal
generator 450 on LQM channel #1 60L and specifically LQM

10   timing bit 311 to provide timing adjustments at the
corresponding field unit 42A as mentioned.

If a field unit 42A in the standby mode transmits a
request to go active, such a request is detected at
heartbeat correlation filter 445. The timing

15   characteristics of an active mode request detected at
heartbeat correlation filter 445 is also analyzed to
determine timing errors as described above for maintaining
alignment on a particular link between the base station 25
and each field unit 42A.

20   If resources are available for allocating traffic
channels 55T, the requesting field unit 42A is placed in
the active mode by base station 25, where configuration
details are handled by processor 426. For example,
information of new LQM time slot assignments, *i.e.*,

25   assignment of an active mode time slot A1-A16, is achieved
by sending messages to a corresponding field unit 42A over
the paging channel 60P. Reverse link traffic channels 55T
are then allocated for transferring a data payload from the
field unit 42A to the base station 25.

30   While in the active mode, synchronization of the
forward and reverse link is maintained between the LQM

channel 60L and traffic channels 55T since the heartbeat channel time slot is no longer dedicated on the reverse link 65 to the field unit 42A.

Messages transmitted by a field unit 42A in the active

5   mode are transmitted to base station 25 on the traffic channel 55T. The received traffic channel signal is fed into the traffic channel correlation filter 430 for detection of a timing marker. Preferably, the field unit 42A transmits a sequence of 32 pilot symbols in an assigned

10 time slot as a timing marker. The traffic channel 55T is then analyzed by pulse timing analyzer 420 where it is determined whether messages transmitted by the field unit 42A on the traffic channel 55T are early or late with respect to a desired synchronization of the field unit 42A

15 with the base station 25.

The process of analyzing a pulse or marker for estimating the centroid is similar to that described earlier in the specification for messages and corresponding markers (short PN codes) on the heartbeat channel 55H.

20 However, in the present case, pilot symbols in the traffic channels 55T are used as a timing reference mark rather than short PN codes. Again, see Fig. 6 and related discussion above for details.

Similar to alignment of the heartbeat channel 55H and

25 LQM channel 60L, timing synchronization is maintained between the reverse link traffic channels 55T and forward link LQM channel 60L while a field unit 42A is in the active mode. Timing alignment of the base station 25 and field 42A unit is based upon the LQM timing bit 311 in an

30 assigned active time slot A1-A16 on the forward link 70.

When the receipt of data messages transmitted by the active field unit 42A are received early or late with

respect to an assigned time slot, the LQM timing bit 311 is set accordingly to advance or retard timing of future message transmissions on the traffic channels 55T.

One or multiple traffic channels 55T are optionally analyzed to coordinate timing alignment between the reverse link 65 and forward link 70.

As mentioned, the access channel 55A is used by field units 42 to transmit requests for establishing communication links with the base station 25. Typically, messages on the access channel 55A are transmitted on a random basis. Hence, a message collision may occur if two or more link requesting field units 42 happen to transmit a link request message on the access channel 55A at the same time.

If a collision is detected on the access channel 55A, the collision is made known to the field units 42 based upon a message generated by paging channel signal generator 455 over paging channel 60P. Each field unit 42A will then retransmit their request to establish a new link on the access channel 55A based on a random back off time, making it less likely that a collision will occur in a second or other subsequent attempt.

The access channel 55A, also shown in Fig. 4, is fed into access channel correlation filter 435. Preferably, field units 42 transmit a sequence of 32 pilot symbols including data identifying the link requesting field unit 42A. A received sequence of pilot symbols is analyzed by pulse timing analyzer 422 to determine initial timing information of the access channel 55A with respect to the base station 25. Since the field units randomly transmit on the access channel 55A, it is necessary to determine an initial timing error between the field unit 42A and base

station 25 for achieving a coarse synchronization of the
forward and reverse link channels.

If it is determined by base station 25 that a link
will be established between base station 25 and requesting
5   field unit 42A, an appropriate acknowledgment message is
transmitted over the forward paging channel 60P to the base
station 25. Among other information transmitted over the
forward paging channel 60P to the field unit 42A, a
heartbeat time slot assignment, an LQM time slot
10   assignment, and synchronization information is also
transmitted to field unit 42A.

Coarse timing correction information is transmitted on
the forward paging channel 60P to roughly synchronize the
link requesting field unit 42A with respect to base station
15   25. A 10 bit signed number is transmitted to the field
unit 42A indicating an amount to advance or retard timing
with respect to the previous link request message
transmitted on the access channel 55A and received at the
base station. Preferably, each least significant bit (LSB)
20   in the 10-bit signed number is weighted such as 16 chips
per LSB. Based on this timing correction information, the
corresponding field unit 42A adjusts its coarse timing
relative to the base station 25. Thereafter, messages are
then transmitted in the appropriate reverse link time slot
25   on the heartbeat channel 55H or traffic channel 55T, which
will be analyzed at the base station 25 as mentioned above
to fine-tune synchronization of field unit 42A.

In addition to transmitting in the appropriate time
slot, synchronization with base station 25 renders it
30   possible for the field unit 42A to receive information in
its assigned time slot.

Figs. 5a and 5b is a flow chart providing details of
how a wireless communication link is established between a
field unit 42A and the base station 25. There are
occasionally multiple field units requesting communication
5 links in a particular service area, where each mobile or
field unit 42A is typically located at a different distance
with respect to the base station 25. Hence, the time it
takes for a signal to travel from a particular field unit
to base station 25 is different for each field unit.
10 Precise timing alignment of a specific field unit 42A and
base station 25 can be helpful to avoid or minimize
collisions between field units transmitting in adjacent
time slots.

Not only does distance from a field unit 42A to base
15 station 25 effect timing alignment, so does the environment
in which a field unit 42A transmits a message. For
example, building structures, atmospheric conditions and
other geographical terrain will effect the path of a signal
transmitted from a field unit 42A to the base station 25.
20 A field unit 42A changing position merely a few feet in
several seconds therefore can have a substantial impact on
timing of a signal path, thus, effecting timing alignment
between a reverse link 65 and forward link 70. Based on
the principles of the present invention, the previously
25 described method of continuously adjusting transmissions in
the shared reverse channel 65 minimizes collisions among
messages transmitted to the base station 25 in adjacent
time slots.

Step 510 in Fig. 5a shows the entry point of the flow
30 chart for establishing a wireless communication link. The
access channel 55A is monitored by base station 25 to
detect requests by field units 42 to establish wireless

links with the base station 25 in step 515. A link request
message received at base station 25 includes a sequence of
pilot symbols followed by data identifying the link
requesting field unit 42A. Based on this information, the
5 base station 25 is able to access details regarding a
particular subscriber and the characteristics of the
corresponding field unit 42A.

As shown in step 520, if no time slots are available
for establishing a new link, the connection request is
10 denied in step 525. Messages related to the denial of a
new link are transmitted to the corresponding field unit
42A on the forward link paging channel 60P.

If resources are available to establish a new link in
step 520, base station 25 analyzes the timing of the
15 request message received by a field unit 42A on the access
channel 55A in step 530. As mentioned, the sequence of 32
pilot symbols are analyzed to determine the location of the
peak pulse or marker in the reverse link 65. Based on the
time when this potentially random link request message is
20 received with respect to the base station's master time
reference EPOCH mark M1 and the distance that the field
unit 42A is located from the base station 25, a coarse time
adjustment message is generated by the base station 25 to
synchronize timing between the link requesting field unit
25 42A and base station 25. This coarse timing information,
preferably a 10 bit signed number indicating how to align
the field unit with the base station EPOCH is sent to the
field unit 42A over the forward link paging channel 60P in
step 535. The field unit 42A then adjusts its timing
30 accordingly so that it transmits messages in its assigned
time slot on the reverse link 65 and also listens during

the appropriate time slot to receive messages from base station 25.

Additionally in step 540, base station 25 assigns two time slots to the link requesting field unit 42A over

5   paging channel 60P. One assignment is a time slot in the forward link LQM channel 60L, indicating the time slot in which the field unit 42A is to receive LQM messages from the base station 25. The second assignment is a time slot in the reverse link heartbeat channel 55H in which the

10   field unit 42A is to transmit messages to base station 25. Based upon these time slot assignments, the base station 25 and field units 42 determine to which link between the base station 25 and one of many field units 42 a message is directed.

15   A set of short PN codes is also transmitted to the field unit 42A over the forward link paging channel in step 540. Each short PN code corresponds to a predefined message that is potentially transmitted in a reverse link time slot to base station 25. For example, one code

20   corresponds with a request by the field unit 42A to remain in the standby mode while another code corresponds with a request by the field unit to be placed in the active mode. Short PN codes can be chosen from a pool of 2^{32} unique codes, where none of the codes in the assigned sets of

25   codes to each field unit is duplicated. However, a common set of codes can be assigned for use by multiple field units 42.

While in the standby mode, base station 25 monitors periodic messages in an assigned time slot for a particular

30   short PN code transmitted by the corresponding field unit 42A. For example, the short PN code pulse is analyzed at base station 25 to correct timing alignment as mentioned

between the forward link LQM channel 60L and reverse link
heartbeat channel 55H. If a message in a time slot is
early or late at base station 25, timing of the short PN
codes on reverse link heartbeat channel 55H is

5   appropriately retarded or advanced based upon the LQM
timing bit 311 for a particular field unit 42A in step 542.

Timing adjustments are made at the field unit 42A
based upon the state of the LQM timing bit 311. Initially,
timing is corrected by 1/8 of a chip in the appropriate

10   direction depending on the state of the bit. If the field
unit receives 8 retard bits in a row or 8 advance bits in a
row over as many EPOCHs, timing adjustments at the base
station are based on ½ of a chip instead of 1/8 of a chip
for the following same state LQM bits 311. In this way,

15   synchronization between the base station 25 and field unit
42A is achieved more quickly.

Once the field unit 42A determines that timing is
overcorrected, i.e., the polarity of the LQM timing bit 311
changes, the timing adjustments at the field unit 42A

20   revert back to 1/8 of a chip adjustments for each received
LQM timing bit 311. When synchronization is achieved
between the field unit 42A and base station 25, the LQM
timing bit 311 will typically be set to alternating logic
ones and zeros for several successive EPOCH cycles. In

25   other words, timing at the field unit 42A will jitter 1/8
of a chip when synchronization is practically achieved
between base station 25 and field unit 42A.

If field unit 42A receives another 8 cycles of timing
adjustment correction in the same direction such that the

30   state 16 successive LQM bits 311 are the same state, the
time adjust correction is set to 1 chip per received LQM
timing bit 311. As stated earlier, when over-correction is

detected, chip adjustments at the field unit 42A are set to 1/8 of a chip again.

In addition to monitoring timing pulses for aligning message transmissions of each field unit 42A, base station 5 25 monitors the short PN code received in each time slot on the heartbeat channel 55H in step 545. It is then determined in step 547 whether the short PN code received at base station 25 corresponds to a request by the field unit 42A to be set to the active mode. If so, the base 10 station allocates appropriate resources such as traffic channels 55T in the reverse link 65 to support the data transfer in step 550. Additionally, the field unit 42A is assigned an active time slot, *i.e.*, one available time slot between A1-A16, in the forward link LQM channel 60L. While 15 in the active mode, as mentioned, the field unit 42A maintains synchronization with the base station 25 based on a sequence of well-placed pilot symbol markers in the traffic channels 55T, upon which the base station 25 issues timing adjustments in the appropriate time slot of the 20 forward link LQM timing bit 311. In step 555, the field unit 42A transmits data in the reverse link traffic channels 55T before returning to the main loop again at step 560.

If a field unit 42A has not been in the standby mode 25 too long in step 560, base station 25 determines in step 572 whether the field unit 42A has made a request to terminate a wireless link between base station 25 and field unit 42A. Without detecting a request to tear down a link, processing loops back to step 542 for fine-tuning timing 30 adjustments as previously described.

If field unit 42A makes a request to tear down a corresponding link in step 572, base station 25

acknowledges such a request in step 575 by sending a message to field unit 42A. Additionally, the base station 25 tears down the communication link. This is one way of terminating the flow chart as shown in step 580.

5   Referring again to step 560, if it is determined that field unit 42A is inactive too long, *i.e.*, in standby mode not transmitting data, the base station revokes the assigned LQM and heartbeat time slots for use by other users and maintains an idle connection with the field unit
10   42A in step 565.

When field unit 42A requests to go active again in step 582, the process flow continues at the beginning of the flow chart to reestablish a link in step 570. In such a case, connectivity is reestablished based in part on the
15   prior connection. For example, it is not necessary to go through the entire configuration process as data maintained with respect to a recently active link is advantageously used to minimize the overhead associated with reviving the previous connection.

20   Flow continues at step 585 if the base station 25 fails to detect a request by the field unit 42A to go active again. If the base station 25 fails to receive a response from an idle field unit 42A in a specified time out period as in step 585, the base station pings the field
25   unit on forward page channel 60P to elicit a response by the field unit 42A in step 587. If the field unit 42A does not respond in step 590, it is assumed that the field unit 42A is shut down and an idle connection is no longer maintained for that particular field unit 42A. If the
30   field unit 42A responds to the ping in step 590, the routine continues in step 595 to reestablish the link as a standby connection at the start of the flow chart.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein

5 without departing from the scope of the invention encompassed by the appended claims.